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The concept of human factors - a discussion of risk assessments

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Preface

This project started in August 2002 and is a collaboration with Det Norske Veritas (DNV). DNV concluded their part of the project during summer 2002 (DNV 2003), and this report is therefore a further treatment of the issue by Rogaland Research on an independent basis, but in dialog with DNV concerning aim and approach. Both parts of the project are part of the research programme HSE Petroleum administered by the Research Council of Norway.

The authors would like to thank our informants in the Norwegian petroleum industry, without whom this report would not have been possible, as well as interest-groups within the same enterprises, for help in solving specific problems.

We would also like to thank Arne Jarl Ringstad at DNV for his assistance in discussions along the way. This has been a great support and guide for our approach to the problem.

Two other persons to be mentioned are Terje Aven and Ove Njå, who have both contributed with constructive comments on our results and our treatment of them.

Stavanger, 22. April 2003

Sverre Nesvåg, project leader

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Summary

Focus on human factors is of increasing interest in the petroleum industry today. Accident investigations show that the human and organizational aspect is present in most incidents, but that it is hard to predict the contribution they make in the early stages.

The original aim for DNV and RF was to develop a method for integrating human factors into risk assessments, in order to increase their value as tools for decision support. During the first phase, and before RF began its work, DNV had revealed that human factors are usually not included in quantitative risk assessments (QRA) in a systematic manner. Our task was therefore going to be hard to solve through a single approach, and so the aim for RF was redefined as study of the conditions for human factors in the context of risk assessments. This meant researching how the concept of human factors is understood and treated within risk assessments, and studying the reasons why it is difficult to include human factors in QRA. Based on findings from these two areas, we then discuss the next challenges within human factors and risk assessments.

In order to obtain answers to our questions we carried out ten interviews with employees in the Norwegian petroleum industry. We also performed a broad literature study of the existing offshore-related material on human factors. The data collected was further treated using the qualitative analytical tool NVivo 2.0 from QSR.

According to our informants the Norwegian petroleum industry is highly engaged in the question of human factors. There is however no doubt that what is meant by human factors has different interpretations depending on whom you ask. Both our informants and the literature have different understandings of this term, and this may complicate the further discussion of the use of human factors. We cannot make a judgement on the correct definition of human factors, but we have identified the common components in the interpretations presented in our material. We have reduced them to a system of four categories. Based on these collected definitions we can therefore say that human factors cover of a) individual factors, b) working environment-related factors, c) organizational factors and d) physical factors. The informants tended to emphasize the first two categories, while the literature stressed the last two. The literary definitions are also more universal than the informants'.

When it comes to the position of human factors in a risk assessment context, this is to a large extent dependent on how the term is interpreted. It is evident that some human and organizational aspects are included in most risk assessments, but mainly for qualitative risk assessments in the production phase. The problem is that these assessments are performed separately from the quantitative risk assessments, which are carried out in the design phase and usually by consultants.

Project reports within this field do not rule out the possibility of quantifying the human contribution in risk assessments, but they do warn against using limited values. The reports show an enthusiasm for finding a way of implementing human factors when quantifying risk, while some of our informants disagree with this. They do not appear to

feelany need for new methods, because they say there are already too many methods that are not in use.

Based on the findings of how the concept of human factors is interpreted in relation to risk assessments, we propose dividing the term human factors into three. The aim here is to discuss in what forms human factors can be integrated into risk assessments, if this is required. Human factors can best be quantified through *human performance*, and mainly in the form of human error. Usable error frequencies are however dependent on solid accident investigations and uncertainty must be taken into account. Behind human performance we find *performance shaping factors*, which are the root causes of human error. These are unfortunately difficult, and sometimes impossible to quantify, but they do cover all influencing aspects such as organization, training and group processes. Performance shaping factors are therefore more important to study than human error, but require a different approach. The last component is what is known as *barriers*, which are meant to prevent incidents from developing into accidents. The incidents themselves may for example be the result of human performance, but when viewing barriers as merely technical appliances, they can be said to be quantifiable. However, considering barriers in the terms employed by the Norwegian Petroleum Directorate, as being technical, operational or organizational, the quantification becomes more complicated. According to this view, barriers include both human performance and performance shaping factors in addition to technical issues.

This report does not answer the question of how human factors can play a greater part in risk management, but it does is emphasize the need for cooperating across disciplines in order to increase understanding of the interplay between human and technical factors. This need is substantiated by the large amount of work already done on human factors and qualitative risk assessments, and on the distance between this and the quantitative assessments. On one hand it is tempting to suggest that QRA should be kept as it is today, since integrating information about human factors would be of limited value. It would obviously be a difficult task to accomplish, and it would probably only make a marginal change to already acceptable FAR-values. On the other hand it would be wrong to abandon QRA as an already strong decision-supporting tool, by believing that an improvement can not be done. Recognizing that focus on human factors is increasing, it would be a retrograde step not to try to incorporate them in the early stages of an offshore operation.

Abbreviations

BNL	Brookhaven National Library
CIEMAT	the Research Centre for Energy, Environment and Technology
DNV	Det Norske Veritas
FPSO	Floating, production, storage and offloading vessel
GNP	Gross national product
HAZID	Hazard identification
HAZOP	Hazard and operability studies
HFACS	Human factors analysis and classification system
HCLIP	Hydrocarbon and leak ignition project
HOF	Human and organizational factors
HRA	Human reliability assessments
HSE	Health, safety and environment
HSE	Health & Safety Executive
ILCI	International Loss Control Institute
I-RISK	Integrated risk
ISM	Integrated safety model
ISRS	International Safety Rating System
MTO	Man – technology – organization
NFR	the Research Council of Norway
NPD	Norwegian Petroleum Directorate
OGP	Organization of Oil & Gas Producers
OLF	Norwegian Oil Industry Association
ORA	Operational risk assessments
PSA	Probabilistic safety assessments
PSF	Performance shaping factors
QRA	Quantitative risk assessments
RIF	Risk influencing factors

SAM	System – action – management
SIS	Safety information systems
SJA	Safe job analysis
WPAM	Work process analysis model

1 Introduction

This report covers the continuation of a project carried out by Det Norske Veritas during the summer of 2002 (DNV 2003). The two projects lie within the research programme “HSE Petroleum” initiated by the Research Council of Norway (NFR).

First we need to give an account of the aim of the project. According to the terms of NFR, this project is a user-initiated project (BIP), as opposed to a competence project with user participation (KMB). This means that the work done within this project is based on dialogues about our principal’s (i.e. DNV) request and objective. The results are therefore with reference to defined approaches agreed between DNV and Rogaland Research (RF).

Both institutes were committed to the same goal, although in different phases. The original aim, as formulated in the application from DNV to NFR, was to establish a method for the integration of human and organizational factors (hereafter referred to as ‘human factors’) into risk assessments. As part of this, information was to be collected about the industry’s practice and needs regarding an integration of human factors in risk assessments. This, together with a study of existing research and methods within the area, would lead to a new method, which in the final instance could be tested.

It soon became clear that this aim would be impossible to achieve. DNV’s found stated that human factors are not included in quantitative risk assessments (QRA). It was also clear that there exists no single, simple solution to this issue, and that a range of approaches would be required (DNV 2003). Through dialogues with DNV the aim for RF’s effort was therefore changed, and the purpose of further work was instead directed at studying the conditions for human factors in the context of risk assessments. The main questions posed were:

- How are human factors understood and treated within risk assessments?
- Why is it difficult to include human factors in quantitative risk assessments?
- How can findings from these two questions be used in further work within human factors and risk assessments?

Before entering into the discussion about findings, a short introduction to the Norwegian petroleum industry will be given, together with the external conditions that apply on the Norwegian continental shelf.

1.1 The Norwegian petroleum industry

The first oil on the Norwegian continental shelf was found by Exxon Mobil in 1966, and 1971 was the first year of Norwegian oil production, in this case on Ekofisk, with Phillips as operator. Today there are about 50 offshore installations on the Norwegian continental shelf, and oil production constitutes 23% of total GNP and 45% of all Norwegian export (2001). Two departments are responsible for this industry, the

Ministry of Petroleum and Energy and the Ministry of Labour and Government Administration. The former is responsible for matters concerned with the use of resources, while the latter is responsible for health, safety and environment (HSE[1]). The Norwegian Petroleum Directorate (NPD) has responsibility for both of these areas, and is therefore an advisory agency for both departments and the regulatory authority for the petroleum industry. The oil producing companies have to act in accordance with the requirements of the NPD and its regulations (Zachariassen 2002).

1.1.1 Regulations concerning health, safety and environment

The petroleum industry is subject to five regulations regarding HSE[2]. They were all laid down in August and September 2001, and came into force on January 1st 2002.

The NPD states that all petroleum companies within its sphere of authority shall have made thorough risk assessments before starting oil or gas production on an offshore installation. The production companies are thereafter required to update the risk assessments when changes are made which are likely to affect the risk level. These overall risk assessments, which we from now on will call quantitative risk assessments (QRA), result in a figure that illustrates the total risk level for the installation. This subject will be dealt with further in chapter 3.

1.1.2 The use of information about incidents

There exist several different systems for registration of incidents and accidents. The systems vary according to purpose and the type of incidents they cover. These safety information systems (SIS) are also used to determine which incidents are to be reported to NPD and which are not. One example of SIS is Synergi, which is used by several Norwegian petroleum companies. Synergi is based on the ILCI model[3], which is also a central element in ISRS[4]. The ILCI model describes an accident in five stages: 1) scarcity of control/direction, 2) root causes, 3) direct causes, 4) contact/energy transmission and 5) loss (Aven et al 2000). Synergi consists of a matrix where the personnel are supposed to assess the extent of loss in terms of human suffering, lost

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1 This is also the designation for UK's Health & Safety Executive

2 Regulations relating to health, environment and safety in the petroleum activities (rammeforskriften), Regulations relating to management in the petroleum activities (styringsforskriften), Regulations relating to material and information in the petroleum activities (opplysningspliktforskriften), Regulations relating to design and outfitting of facilities etc. in the petroleum activities (innretningsforskriften) and Regulations relating to conduct of activities in the petroleum activities (aktivitetsforskriften).

3 International Loss Control Institute

4 International Safety Rating System

reserves or lost capital. About three-quarters of the incidents registered in Synergi are so called “green” incidents, which only require administrative actions.

Following occupational accidents, leaks or major hazards, investigations will often be carried out. These seek to find deeper causes than those that are probably evident at the place in question, for example performance shaping factors (see 3.2.2). Some investigations are carried out by the companies themselves while others are required to be performed by representatives from the authorities.

In the collaboration project “Cooperation for safety” work is directed at establishing a common matrix for the categorisation of undesirable incidents. The aim is to prepare joint guidelines for the reporting, follow-up and investigation of undesirable incidents. It is claimed that this would be useful both for the NPD and for the contractor companies (see Samarbeid for sikkerhet 2002).

There is however a common database for the registration of leaks, and this has been in use by all production companies on the Norwegian continental shelf since 2001 (Nilsen and Jakobsen 2002). The database is called the Hydrocarbon Leak and Ignition Project (HCLIP) and is referred to in the NORSOK standards[5].

The best general data source for occupational accident statistics in Norway is the annual report from the NPD. This report summarises the number of working hours, injuries and fatalities on fixed installations and on mobile units during the last ten years in the Norwegian sector of the North Sea. Still, occupational accidents are of less importance in our context, although they can be used as good indications of where to focus.

1.2 Placing human factors in a risk context

The petroleum industry has traditionally been largely concerned with technical issues and solutions. This is also the case with risk assessments, where QRA has long been a tool for design, to be used in a phase where the human aspect is not yet a part of the installation. It is therefore a challenge to discover where and how human factors influence the risk level. The NPD now requires that QRA also be used as a tool for decision support in the production phase. Because the organization and people on board the installation are involved in causing many of the failures in this phase, the QRA should take these into account. Unfortunately there are few channels today through which these aspects can be pointed out, and an update of the QRA often leads to the same result as the initial QRA.

The phrase “If you can’t count it, it doesn’t count” still represents the prevalent view. At the same time, different comprehensions are used depending on the daily challenges people have to deal with. There are numerous risk assessments where the human aspect is included or may even form the main topic, but these are generally not related to QRA.

5 NORSOK standard Z-013:9 (NORSOK: Standardisation in the petroleum sector)

The risk assessments that include human factors are usually performed separately from those dealing with major hazards and overall risk level. However, the last decade or two have shown how organizational factors are increasingly contributing in major accidents (e.g. Challenger, Chernobyl and Piper Alpha) (Bellamy 1994, Gordon 1998).

1.3 Approach

This report will provide a sort of "state of practice", primarily for the Norwegian petroleum industry, regarding the inclusion of human factors in risk assessments. It will also give an account of the wide theoretical and practical use of different expressions within the field of 'human factors' and the field's relation to risk assessments.

The present project is based on qualitative methods, including both literature and interviews. To make thorough use of the data collected, we have used the qualitative analytical tool NVivo 2.0 from QSR.

1.3.1 Literature review

In order to give a thorough outline of the current situation regarding human factors in risk assessment, it was necessary to go through a wide spectre of articles, reports and other documentation. It is no secret that the petroleum industry is not as preoccupied with academic and theoretical issues as the researchers who want to study it. One of the challenges in this project has therefore been to be able to "meet the industry halfway", which may open the report to criticism of its academic validity. It is however important that the industry should be seen for what it is, and not in a way that researchers might want it to be.

1.3.2 Interviews

A purely literature-based project would in this matter probably have been incomplete. Alternatively one could have executed the project based solely on interviews, which would have raised the danger of spending too much time and resources on doing just that. Taking into consideration our initial knowledge and experiences, it was clear that an overall impression of the industry's work could better be obtained by combining interviews with the study of existing literature.

The interviews in this study have functioned both as pure information channels about certain subjects and as justifications of the chosen approach. More than once we have had to change our angle of attack to take account of new things we have learned on the way. In that respect, this project has been a continuous development of our understanding of the problem.

Altogether we have carried out ten interviews with nine different persons. Eight of them work in petroleum, while the last person works in the aviation industry. The link to aviation is made on the basis of problem similarities and on the need for comparison with other industries' work. The eight respondents from the petroleum industry are employed in four different oil companies, all of them operators on the Norwegian Continental Shelf. None of our informants actually prepare major hazard QRA today, as this task has been transferred to external consultants. Three of them are however directly connected to QRA through their daily work, while four informants work indirectly with such assessments. One informant works within other risk assessments and with human factors in particular.

Although the field is large and the amount of expertise is difficult to maintain an overview of, we have seen that the interviews have led us to a clear limit for the challenges of this issue. In spite of and because of the width of the informants' working fields, we believe that we have managed to arrive at a realistic view of the situation.

2 Human factors in the petroleum industry

To approach the question of human factors integration, we find it appropriate to give an account of present thinking on human factors and the impressions we received when confronting the industry with this subject.

The first surprise came from the informants' willingness to talk to us. 'Human factors' is obvious a relevant subject for the industry today, something that is evident from the number of seminars and workshops currently being arranged[6]. The expected reluctance to reveal details about current work within this area has apparently been overcome by a common wish to share in other companies' experience in order to improve one's own efforts.

2.1 Human factors – a new concept?

New concepts are introduced from time to time, both in social and economic life. Some are new expressions with old content, and others intend to introduce something with actual value. Although the term 'human factors' has been used for a long time (see for example Bellamy 1994), it sometimes seems to be a kind of catchword. It is however worth noticing that this is related only to our investigations in the Norwegian petroleum industry. Some of our informants claim that human factors are more established in for instance the USA than in Scandinavia. In Norway the NPD has great influence in deciding what the industry should be focusing on. Introducing the term "HSE-culture" in its new regulations (see 1.2), the NPD contributed to the industry's increasing focus on this and related issues. Strictly speaking 'human factors' is not a part of the new regulations, but the so-called "HSE white paper" which among other things emphasizes organizational factors in connection with emergency preparedness (Arbeids- og administrasjonsdepartementet 2001-2002).

A complicating factor is the difference between human factors and the term man – technology – organization (MTO), which the NPD has introduced to the Norwegian petroleum industry in relation to accident investigation. Over the years this term has acquired a wider meaning, but we have not been able to identify what our informants' particular understanding of MTO is. Yet it is striking how this division into three also resembles the structure of human factors, as will be shown in the next sections.

6 E.g. the NPD's seminar on HSE-culture in November 2002 and IFE's (Institutt for energiteknikk) three seminars regarding MTO (man – technology – organization) autumn 2002.

2.2 Different interpretations of 'human factors'

In order to map the challenges connected to risk assessments and human factors, it was necessary to clarify the industry's work and understanding within the field of human factors. During this work it became clear that using the term 'human factors' could lead to misunderstanding, not because the term itself is unintelligible, but rather because interpretations of it vary and are partly incompatible. Talking about human factors is therefore only easy until someone asks for a definition (see also McLeod et al 2002).

2.2.1 The informants' view

When talking with informants some confusion concerning human factors was uncovered, because until then it had seemed that there existed only one meaning, although this was unknown for us at that time. The significance of this was wider and less defined than first assumed.

Some people think that human factors cover all human activity, while others believe that you have to consider people in everything you do. This view affects maintenance and manning of an installation, among other things. One of the informants divided the concept into two parts, one *soft* side, consisting of inter-human conditions, and one *hard* side, comprising the physical factors such as design. Another view placed human factors somewhere within HSE-culture, by defining HSE-culture as everything *not* touching procedures and hardware, leaders' attitude and so on. Of the more precise but still wide definitions are those that connect human factors to ergonomics and work environment, as well as to probability and consequence. Others link the term directly to the influence of human error in an incident and the likelihood of humans acting in accordance with plans and procedures, either conscious or unconscious. Last, but not least, we have the ones who emphasize the MTO-notion when talking about human factors, although they still may not be capable of defining this term either.

In the interviewing process, one of the informants questioned the need for definitions at all. First, he said, it is a tedious and difficult work, and second it looses its intention if it leads to the omission of vital parts.

2.2.2 The literature's view

Before entering our study of literature, we once again want to note that this also includes reports and less academic texts than are normally approved as background material in published articles. These are however more useful to us than the best article, because of their direct link to the industry's own policy and work.

As mentioned before, the interaction between man and machine is a popular definition of human factors (Gordon 1998, Mearns et al 1997). Sometimes during the 1990's this definition was extended to encompass the effects which individual, group and organizational factors have on safety (see also Wilpert 1995). This definition is in many ways similar to the one we find in HSE (1999), which refers to "environmental, organizational and job factors, and human and individual characteristics that influence behaviour at work in a way that can affect health and safety". This definition is also used by DNV in their work with human factors (HSE 2002).

When it comes to HSE, it is one of the leading actors within human factors. As advisory agency, it has published several reports and prepared training material for the petroleum and other industries. One report states that human factors area "professional discipline concerned with improving the integration of human issues into the analysis, design, development, implementation and operational use of work systems" (Widdowson and Carr 2002). This implies the interaction between humans and technical system components, such as operating, monitoring and maintaining in accordance with training and work organization. The report also divides human factors activities into six general areas, called the factor domains of the human factors integration process. The six domains are staffing, personnel, training, human factors engineering, health hazards and system safety.

Sometimes interest groups use their own definitions. One such organization is the Organization of Oil & Gas Producers (OGP), which states "Human factor is the term used to describe the interaction of individuals with each other, with facilities and equipment, and with management systems. This interaction is influenced by the working environment and by the culture of the people involved. [What may be a good system of work in one part of an organization, may be found to be less than ideal in a region where culturally driven attitudes to risk taking may be significantly different]"(www.ogp.org.uk).

The term 'human factors' is even used interchangeably with the term 'ergonomics' (Kirwan 2002), which refers in its turn to human performance in work context. In this sense, human factors relate to the objective problem (for example design) as well as to the social and subjective working environment of the consultant or the industrial practitioner who is supposed to solve the problem.

Bea et al (1996) discusses human factors as including people, equipment (such as hardware), management systems and culture and environment (cited in Vinnem et al 2000). As for some of our informants, human factors are also seen in connection with human errors. According to DNV, there is still some disagreement concerning the two areas and their precise nature and definition (Widdowson and Carr 2002).

2.2.3 Summary of the interpretations of 'human factors'

As the reader may have noticed, there are countless ways of understanding this concept. We are not in a position to say whether any of them is right or wrong, but we do record the variety of meanings that this term gives rise to. The literature's interpretations are often based on interviews or in other ways related to actual understanding, but there is still no single definition on which either the entire literature or our informants agree.

It is possible however to identify certain main categories in the different interpretations and definitions. By putting the components from our informants' and the literature's interpretations into a matrix, we can say that roughly human factors exist of a) individual factors, b) working environment, c) organizational factors and d) physical factors. These categories go some way to systematizing the elements that human factors comprise in our material. It does *not* reflect our opinion of the term, and as the categories cover a wide range of aspects, they do not bring us any closer to a single definition.

One interesting result is that our informants tended to mention the individual factors and the working environment, while the literary definitions were more preoccupied with organizational and physical factors. An explanation for this can be that the informants emphasize safety through individual and group behaviour, while the literature stresses the 'safety system' represented by organization and design. This again can be seen in connection with the question concerning human or organizational failure. Another result is that the informants mention small important components while the literature operates with entire ideas. Yet another study shows that several of these isolated components, when placed in the same category in our matrix, touch the same elements as the larger definitions.

The four categories together cover a large area and do not lead us to a more precise definition. Some interpretations are even held on one side, and among these are the ones concerning MTO. The reason for not making MTO a separate category is that it touches both the first and the two last categories, and emphasizes the interaction between them. This can explain why some informants draw a direct line between human factors and MTO.

Ideally we should either choose one of the existing definitions or make a new one, in order to use this as the common understanding for further work on the subject. It is not our aim however to decide on one single definition, but rather to give an overview of the existing conceptions.

Due to the different interpretations, the correlation between MTO and human factors is not unexpected, but it does not cover the category of 'working environment'. Culture is a major part of this category, and something which is mentioned increasingly often in safety-related discussions. Related to our matrix, MTO is too narrow a term, as well as not being a real definition.

During our work the suggestion was made of using OGP's definition as a common understanding, as it is already used by one of the companies represented in our material. Unfortunately the definition is too wide and imprecise, as it includes everything that can possibly influence a working situation. Even though this also can be said of some of the other literary definitions, Widdowson and Carr (2002) have shown how it is possible to limit a definition within our four constructed categories (for both definitions, see 2.2.2).

When all this is said, it is important to point out that this applies for the petroleum industry specifically in Norway and the UK. We agree that human factors have a different position in for example the aviation industry. Aviation could thus be seen as a leading industry, with its long traditions within this field, but we will however not pursue this particular discussion.

3 Human factors in risk assessments

During the last few decades several major accidents have demonstrated the influence of human and organizational factors. This applies for Chernobyl and Three Mile Island as well as for Piper Alpha (Gordon 1998). The significance of human related factors has therefore been known for a long time. Nevertheless it seems that the petroleum industry is still eager to estimate and reduce technical risks in isolation rather than seeing them in a human and organizational context (Vinnem et al 2000).

Viewed against this background, all the informants we have contacted claim that their company has a broad approach within human factors. It is a subject that the companies find it useful to focus on. How they work with it is however dependent on their interpretation of the term, but human factors form part of projects and risk assessments throughout the organizations. Regardless of this, it is clear that, with few exceptions, human factors are *not* included in QRA. QRA is still reserved for the technical approach, including numbers and estimations of possible technical errors.

It is important to stress that we have not been given the opportunity to study any of the companies' QRA's, and that our statements are therefore solely based on information given by our informants. Several efforts were made to get access to such information, without success.

One informant claimed that QRA includes human factors through the FAR-value[7], because the FAR-value is based on the number of personnel on the installation. Another informant stressed the human or organizational contribution through frequencies for human error or for example leak-frequencies. In this connection, the different databases containing information about former incidents are of great significance, as they are used as background material for risk assessments. The need for a closer link between these data and the QRA should therefore be stressed, because this would make it possible to investigate more closely the effects of human factors on the general risk level. Some informants underline the fact that historic data that include human error *will* affect the probability of a leak out break, but that it is hard to quantify the *proportion* of the total leak frequency that is directly attributable to human actions.

Some engineers are reluctant to talk about human influence in subjects related to QRA. This may be because they think it is irrelevant and discussion a waste of time, although it is more probably because they are aware of how difficult it is to make QRA reflect human intervention. Some engineers believe that major hazards, which are the main focus of QRA, simply cannot be triggered by human actions alone, and that even if this were possible, the technical barriers would prevent the accident from escalating.

7 Fatal Accident Rate: expected loss of life per 100 million exposed hours. The NPD requires that the FAR-value for an installation lies below 10.

When all this is said, it is important to note that human factors, independent of their interpretation, are included in several risk assessments other than QRA. The most common assessments are hazard and operability studies (HAZOP), hazard identification (HAZID), "What-if" analysis and safe job analysis (SJA). There are also assessments that consider the human aspect directly through the possible occurrence of human error. These are for example human factors assessments and human reliability assessments (HRA). In addition risk assessments are sometimes also specially constructed to meet the companies' own challenges. Within all these areas human factors play a major role, both through direct human influence and through organizational changes.

3.1 Efforts in integrating human factors in risk assessments

Based on the previous section it seems that human factors have a difficult time when it comes to risk assessments of the quantitative type. Nevertheless we would like to present some contributions that have been made to approaching this problem. For a broader description the reader should consult the references.

In 1998 the NPD raised with SINTEF the idea of a project on risk analysis in the production phase. The report based on literature studies stated that there have been few attempts to coordinate qualitative research with quantitative risk analyses of the technical system. The aim of the previous and present projects has been to make the estimate of risk more accurate and the effect of organizational changes easier to evaluate. To achieve this, one has to ensure a better integration between organizational factors and risk analyses. One main impression is that the research within risk indicators and organizational factors is immature, and that one lacks recommendations about reasonable techniques. The methods mentioned (WPAM, I-RISK, the CIEMAT project, SAM, ISM and the BNL project[8]) are not referred to in any standards for risk analyses. This can be explained by the variety of disciplines involved, for example organization theory, human factors, human reliability and risk assessments (Øien and Sklet 1999).

Another relevant project started in 1996 and finishing in 2002 aimed to "develop models and tools in order to integrate human reliability science into predictive models and tools for analysis of safety on FPSOs[9]" (Vinnem 2003). The project used collision with a shuttle tanker as a case for studying collision risk. During the earlier phases it was found that risk assessments carried out for FPSOs fail to consider human and organizational factors (HOF), and that they are not given enough attention in the design phase. The reason for this is that the predictive risk and reliability techniques traditionally have focused more on technical aspects than on human and organizational ones. The issue becomes even more important when taking into consideration the fact

8 WPAM: Work Process Analysis Model, I-RISK: Integrated risk, CIEMAT: The Research Centre for Energy, Environment and Technology, SAM: System-Action-Management, ISM: Integrated Safety Model, and BNL: Brookhaven National Laboratory.

9 Floating, production, storage and offloading vessels

that technical and human (or operational) factors represents more than 50% of the risk influencing factors (RIF). For further work the authors of the report recommend that all failure modes are included when performing risk assessments of FPSOs. By this they mean human, technical and environmental aspects. The analyses of failure scenarios for FPSOs also need to consider human and organizational errors, and it is important to remember that HOF cannot be analysed separately. When it comes to integrating HOF into QRA, there are plenty of methods, but no examples of practical application. The qualitative analyses require a lot of resources, but the techniques are manageable. On the other hand, data on incidents and effectiveness of barriers can be used in the quantitative analyses, but the latter will be limited by data access. Regardless of this, the project underlines the necessity of identifying for which systems and activities the analyses have to integrate HOF for (Vinnem 2000, Vinnem 2001, Vinnem 2003a).

One of our informants told us about a project where an attempt has been made to expand the application of QRA. The background for this effort is a desire to "activate" the QRA, by focusing on elements lying behind the barriers, which cannot be quantified. The method is based on a completed QRA that has already yielded a FAR-value. One can then look at the main barriers in the QRA, to assess which affecting factors are important and which are not. In this connection barriers can be defined as technical, organizational or administrative functions to be established to prevent the break out of an incident, to prevent an incident from escalating to become an accident, or to reduce the consequences of an accident (see section 3.2.3 for a discussion of this). When important factors are identified, one starts by assessing their influence on the barrier's function. There can be ten to twenty such elements per barrier, and if the most important are strong and well functioning, one may give less attention to the rest. One also assesses the quality and importance of the barrier itself, and what its potential for improvement is. This project also views people and organizations as barriers by virtue of their function, and not as single individuals. As background for this method, one uses reported incidents and information from maintenance and inspections. This is information which is not used in QRA, but which reveals departures or bad solutions since the last round of maintenance. In the follow up of the barriers, one therefore asks how long it has been since the last departure, whether the error has been aligned, and how long it took from the discovery of the error to the alignment. Human and organizational factors are supposed to be a supplement to technical factors.

As a follow-up to the project about risk analyses in the production phase (Øien and Sklet 1999), another project was initiated. This one was concerned with the possibility of quantifying the effect that organizational changes made during the operation of offshore installations have on risk. It was mainly concerned about the risk of gas leaks, and the questions asked revolved around *which* organizational factors influenced the leak frequency, and *how* and *how much* they influenced it. The five suggested organizational factors were a) training and competence, b) procedures, SJA, guidelines and instructions, c) planning, coordination, organization and control, d) design and e)

PM-program[10] and inspection. The conclusion was that it *is* possible to quantify the effects of organizational factors on the risk level, even though there is some uncertainty (Øien and Sklet 2001).

In 2001 another effort was initiated, this time by the Technical Safety Resource Group in the Norwegian Oil Industry Association (OLF). Its title was "Operational risk assessment" and a seminar was arranged in August of that year to review the state-of-the-art in offshore application of risk assessments, and to define OLF's policy for the years ahead. One important policy was to improve the use of risk assessments in the production phase. A limited, initial study was conducted in the first half of 2002, aimed at identifying the users and their needs for operational risk assessments. One of the identified needs was improved modelling of barrier performance, in the broad sense. The effort focused on this aspect, and more work is likely to be carried out in future, possibly in combination with other bodies. This work will focus on integrated modelling of all barrier elements, with a special emphasis on human and organizational barrier elements (Vinnem 2003b).

3.2 Possible perspectives

As we have now seen, the direction of our project is of current interest. Work is being done, questions are being asked, but still no one seems to have the final solution to the problem. At the same time, the industry wants answers, but not necessarily in the form of new methods. In fact, some informants emphasize their relative reluctance about yet another method, referring to the number of existing methods that are not in use. Based on our interviews, the selected literature and discussions during a workshop within this research programme (Rogalandsforskning 2003), we would like to put our thoughts into some kind of a system.

The distinction we want to make is the division of 'human factors' into three parts. This is due to the variety of interpretations that exist concerning the field, and can therefore be seen in relation to the previous section. The partition also represents another way of talking about human factors, by moving from theory to practice. Dividing the concept can help us to refer to human factors in a more accurate way than has been possible until now, and we hope that it will facilitate the discussion of how human factors can be integrated into QRA.

3.2.1 Human performance

Human performance is a broad term, but we will use it in the sense of actions in connection with accidents and near misses. The two terms of current interest are human error and error recovery. Both of them lie within the category 'individual factors' in section 2.2.3.

10 The programmes for all planned maintenance work performed to prevent errors from occurring.

The concepts human factor and human error are often interchanged in the offshore oil industry, without a clear distinction being made between their meanings (Bellamy 1994). Both refer to the human contribution in the cause of an accident (Mearns et al 1997). However there exist several definitions of this notion, such as the one from Rasmussen (1993), which defines human error as "human acts which are judged by somebody to deviate from some kind of reference act … they are subjective and vary with time" (cited in Gordon 1998).

James Reason gives more thorough account of this. In this section we will mainly refer to *active* failures, while the next section deals with *latent* failures (Reason 1997). Active failures are failures that may initiate accidents, while latent failures refer to root causes. Reason also distinguishes between *error types* and *error forms*. Error types refer to the origin of an error, which has the following three stages: *Planning*, concerned with identifying a goal and making an effort to achieve it; *storage*, as in the time elapsed between formulating actions and carrying them out; and *execution*, referring to the process of actually implementing the stored plan. The error types connected to these three stages are respectively mistakes (planning), lapses (storage) and slips (execution). While error types refer to underlying cognitive stages or mechanisms, error forms are varieties of fallibility that appear in all kinds of cognitive activity. Error forms are therefore visible through mistakes, lapses and slips (Reason 1990).

There has been another significant effort in classifying human error, based on Reason's model of active and latent failures. It is called the Human Factors Analysis and Classification System (HFACS) and is directed at investigation methods and the restructuring of post-accident databases. It describes human error as either a) unsafe acts of operators, b) preconditions for unsafe acts, c) unsafe supervision, or d) organizational influences (Wiegmann and Shappel 2001). We consider the three last error types as performance shaping factors (see 3.2.2).

A human error in itself is not a catastrophe, but it can lead to one. Some risk analysts disagree with this statement, as the introduction to this chapter demonstrates. At the same time several informants emphasize the possibility of humans unconsciously challenging or breaking down the technical barriers in case of an incident. The potential for major catastrophes due to human error has been clearly demonstrated even though the incidents have only been minor ones or near misses. It is also said that measures to reduce human error are often among the most cost-effective ways of reducing risk, since nearly all accidents are initiated or exacerbated by human error (HSE 2002, www.tripod.nl).

While human error can trigger an accident, error recovery can prevent them or stop them escalating. Error recovery deals with the positive human contribution in safety-related matters, for example through the detection of a gas leaks. It is said, by the way, that 80% of all gas leaks are manually detected, although most would probably have been detected technically shortly after. These human actions can lead to earlier accident prevention and evacuation of personnel. Unfortunately error recovery is not discussed much in the petroleum industry, although academically it is an increasingly focused subject. In the industry human error is still the main subject of focus. This may be because of the opportunity that arises to reduce human error through accident investigation, while the factors influencing error recovery are harder to reveal.

3.2.2 PSF – Performance shaping factors

There are several different factors influencing human performance, called performance shaping factors (PSF), and these can be related to the categories 'working environment' and 'organizational factors' in section 2.2.3. It is said that "PSFs are similar to the factors such as humidity, temperature and voltage which control the accurate operation of computer systems" (Bolsover et al 1998). PSFs can affect how employees perform their jobs. They can also influence human error, either in a positive or a negative direction, and can comprise among other things resources such as manning and instrumentation), system norms, including incident reporting, safety policy and training, communications (information flow and written documentation) and pressure such as stress or boredom. (Bolsover et al 1998) PSFs can also be related to the distinction between latent and active failures. Latent failures may be poor design, gaps in supervision, maintenance failures, unworkable procedures or shortfalls in training. They may arise from strategic decisions, and as their impact spreads throughout the organization, error-producing factors will be created within the individual workplaces (Reason 1997). A third view is the emphasis on organizational factors as root causes. The general development within this research area represents a movement from the study of direct causes (such as human error) to root causes (organizational error) (Øien and Sklet 1999).

HSE operates with the following definition of PSF: "Factors that influence the effectiveness of human performance and the likelihood of errors. Examples include the design of displays and controls, training, fatigue, environmental and job design factors" (HSE 1999). Another view states the following: "The Performance Shaping Factors are (1) Stress, which alters perception, thought and action, (2) Culture, which controls thought and behaviour, (3) The Meaning of Behaviour, which determines the nature of quality of actions, (4) Self Confidence (as distinct from conditioned confidence) which assures accurate and productive work and (5) The Past controls today's performance" (www.newpsych.org).

Clearly PSF are important in our setting, but they are hard to implement in QRA. The reason for this is more or less obvious; how is it possible to estimate for example culture or self-confidence? PSFs are therefore important to take into account, but the integrating strategy is more indistinct. If one uses accident analysis after an incident, one will succeed in discovering relevant PSFs that lie close to the incident in time, but it will be harder to reveal them in a longer time perspective. Some may disagree with this statement and say that integration is dependent on the PSFs in focus. Competence and experience are examples of PSFs that may be linked directly to human error through quantification. Others could also be mentioned, but most PSF are not suitable in quantitative assessments.

3.2.3 Barriers

When discussing barriers, we mean impediments between an incident and an accident or major catastrophe. The incident can be human made or it can be a technical failure, but barriers are mainly referred to as technical appliances (as in the category 'physical factors' in section 2.2.3). Disagreements are however also present in this matter (see section 3.1).

The NPD has included barriers in its new regulations, which deal with efforts connected to possible accidents, actual accidents and other undesirable conditions that can result in damage. The barriers may be of a technical, operational or organizational kind (Arbeids- og administrasjonsdepartementet 2001/2002), and are therefore different from the category of 'physical factors' constructed from the different interpretations of human factors in section 2.2.3.

The concept of barriers brings us back once again to some analysts' view on the human contribution to accidents. In their opinion barriers are purely technical or hard factors and an accident (defined as an uncontrolled energy release) can only be prevented by such technical barriers. Humans can however increase or decrease the probability of the technical barrier being activated, through the degree to which they react correctly in a given situation. On one side a break in a barrier may be caused by a maintenance failure such as the actual opening of a ventilator, giving free passage. This represents the negative contribution of human factors to QRA. On the other side is error recovery, understood as the human contribution to accident prevention (see 3.2.1). In this relation error recovery can act as a positive contribution from the human aspect to QRA, which today does not seem to allow for the capacity of humans to discover and intervene in situations, reducing the risk for themselves and their colleagues. The reason some informants emphasized this particular point is that most important in a risk context is what you do *not* see. Accidents are a mixture of unforeseen instances, not the result of a malfunctioning detector.

4 Conclusions

First, there is no doubt about the potential for integrating human factors in risk assessments. Although some informants state that their risk assessment work includes the human aspect, there is still a long way to go as far as QRA is concerned. The qualitative assessments are many and obviously have a human and organizational focus, but they are performed with a very different purpose from what applies for QRA. Second, confusion about different terms and methods is evident. We sense problems in communicating certain issues because of the diversity in use and understanding of concepts relating to risk assessments. There is a need for clarification on these terms, in order to increase the cooperation between people who are trying to achieve the same goal. Third, human factors need to be communicated in all parts of organizations. If human and organizational issues are to be integrated into QRA, one has to view safety as a whole and work across different professional disciplines. Today there is too much segregation between those who work with human related issues and those who work with QRA. It is also natural to suggest that the companies take a more active part in the QRA process. Today the work is mainly performed by consultants, something which in our opinion distances or even alienates staff, not only within the head offices, but also offshore employees, from the QRA.

The three different components we presented in section 3.2, serve first of all the need to map what human factors actually represent. The next step is to suggest ways of integrating one or more of these components into the QRA. Human performance is naturally of importance, as it is often the triggering factor of an accident. Human performance can, as we have explained, also serve as a risk-reducing factor when personnel act positively in ways not expected. The easiest way to quantify human performance is through estimating human error, for example through human reliability assessments (HRA). This requires a solid base of data, and represents the biggest challenge. A new installation lacks important error data for several reasons. Firstly, there are not yet any available error frequencies for this particular installation, and data must be collected from comparable installations, which may differ in design and organization. Secondly major hazards happen rarely, and their causes are therefore difficult to fully affirm. The quality of error estimates is moreover dependent on the thoroughness of earlier accident investigation. It is therefore quite difficult to get the full overview of all human contributions to offshore accidents, something which will be reflected in the quality of the QRA.

As has already been mentioned, performance-shaping factors (PSF) are hard to implement in QRA, due to their evident qualitative characteristics. By this we do not mean that PSF are less important for the installation's risk level. On the contrary, these factors may be more and more important to consider when talking about accident risk. For example PSFs are evident through the focus on HSE culture, which is said to influence safety in a number of ways. This is however only one effort, and we believe in the cooperation between different professional disciplines as a way of coupling PSF to human error and error recovery.

Whether it is possible to quantify barriers is more uncertain. If one thinks of barriers as only technical appliances, which are not affected by people, a quantification of their effectiveness is possible. If the NPD version, that is barriers as technical, operational and organizational elements, is used the approach becomes more difficult. Barriers can quickly be connected with both human performance and performance shaping factors, and then a quantitative estimation of effectiveness has a more insecure future.

One question we have to ask is how useful the industry finds suggestions for implementing quantitative measures of human action. As earlier mentioned, each installation is required to have its own QRA, from which the petroleum company determines the installation's FAR-value, which hopefully justifies its solutions. One could therefore ask whether there is any reason to fully integrate human factors into QRA if they already show an acceptable risk level? This is especially true when considering the amount of work that needs to be put in in such cases. It is no secret that after completion QRA easily becomes 'just another document on the shelf', and there may be other ways of using resources than changing decimals in the FAR-value due to more uncertain numbers. This view is strongly underlined by one of our informant's statements: "In quantitative analyses you often have 'bullshit in – bullshit out'. Sometimes a quantitative assessment does not bring you any further. (…) The number is not important, as long as it is placed within the margins. It is possible that the assessment work only serves as a kind of internal medicine, where the people inside the different groups only give nourishment to the others' academic thirst for reports".

In this connection one could suggest a more operational use of QRA. The main focus would still be a continual reduction of the risk level, but not through developing new methods for integrating human factors into QRA. Instead there could be an increased focus on the internal communication about human and organizational factors, and an increased cooperation between different disciplines within and between the petroleum companies. In this way different areas would get a better understanding of other areas' challenges, and could hopefully contribute with expertise relevant for them. On the other hand, concerning the position of QRA today, it would be better to support and further develop this as a tool for decision-making. Although it is reasonable to believe that the different values in QRA already represent uncertainty, it is doubtful whether this could be held as an argument for *not* integrating the human aspect as well. Major hazards *are* influenced by human and organizational issues and ignoring this would be both unwise and reactionary. Human factors will certainly not become less important with time, and the petroleum industry has therefore to continue focusing on this particular subject. Once again we would like to emphasize dialogue between disciplines as a way to increase the understanding of the human aspect in accident risk. How and when a potential human factors integration will come into force is impossible to forecast, as it depends on the petroleum companies' priorities and efforts within the field. A broad integration of human factors in risk related work is however dependent on a more systematic demarcation than we find today of what can and cannot be quantified in risk assessment.

Sources

Arbeids- og administrasjonsdepartementet (2001-2002); *Om helse, miljø og sikkerhet i petroleumsvirksomheten.* Stortingsmelding nr 7. (Ministry of Labour and Government Administration (2001-2002); *About health, safety and environment in the petroleum industry.* White paper nr 7.)

Aven, T. (1994); *Pålitelighets- og risikoanalyse*. Universitetsforlaget, Oslo.

Aven, T., Njå, O. and Sandve, K. (2000); *Sikkerhet og beredskap. Kompendium i Risiko- og sårbarhetsanalyse*. Høgskolen i Stavanger.

Bea et al (1996); Introduction to Human and Organisational Factors in the Safety of Offshore Platforms. In *1996 International Workshop on Human Factors in Offshore Operations*, organised by The University of California Berkley and Primatech, December 15th – 18th, New Orleans.

Bellamy, L. J. (1994); The influence of human factors science on safety in the offshore industry. In *Journal of Loss Prevention in the Process Industries*, Vol 7, nr 4.

Bolsover, A. J., Skramstad, E. and Lyon, A. M. (1998); *Uncertainty in QRA*. 7th Annual Conference on Offshore Installations, December 1998. Det Norske Veritas.

DNV (2003); *Human and organisational factors in risk assessment*. Final report. DNV project no. 25300403.

Gordon, R. P. E. (1998); The contribution of human factors to accidents in the offshore oil industry. In *Reliability Engineering and System Safety*, nr 61.

Gordon, R., Mearns, K., Flin, R., O'Connor, P. and Whitaker, S. (2003); *Factoring the Human into Safety: Translating Research into Practice*. Health & Safety Executive, RR061. University of Aberdeen. HSE Books, Norwich.

Health & Safety Executive (HSE) (1999); *Reducing error and influencing behaviour,* HSG48. HSE Books, Norwich.

Health & Safety Executive (HSE) (2002); *Marine Risk Assessment*. HSE Report OTO 2001/063. Det Norske Veritas. HSE Books, Norwich.

Kirwan, B. (2002); Soft systems, hard lessons – strategies and tactical approaches for the integration of Human Factors into industrial organisations. In Wilpert, B. and Falbruch, B. (eds) (2002); *System Safety. Challenges and pitfalls of intervention*. Pergamon, Elsevier Science Ltd., Oxford.

Mearns, K., Flin, R., Fleming, M. and Gordon, R. (1997); *Human and Organisational Factors in Offshore Safety.* Health & Safety Executive, HSE Report OTH 543. HM Stationary Office, Norwich.

McLeod, R. W., McLeod, K. E. V., Harrison, J. and Richardson, A. (2002); *Human Factors Assessment Model Validation Study: Final Report*. Nickleby HFE Ltd, Glasgow.

Nilsen, T. and Jakobsen, G. S. (2002); *Årsaksanalyse av prosesslekkasjer*. RF Report 2002/117. Rogaland Research. Det Norske Veritas, Stavanger.

Rasmussen, J. (1993); Perspectives on the concept f human error. Invited Keynote Talk given at the *Human Performance and Anesthesia Technology. Society for Technology in Anesthesia Conference*, New Orleans, February 1993.

Reason, J. (1990); *Human Error*. Cambridge University Press, Cambridge.

Reason, J. (1997); *Managing the Risks of Organizational Accidents.* Ashgate, Hampshire.

Rogalandsforskning (2003); Workshop within the research programme "HSE Offshore – decision support" January 16th. No official report is so far published.

Samarbeid for sikkerhet (2002); *Informasjonsbladet Samarbeid for sikkerhet*, nr 1/2002. www.olf.no

Vinnem, J. E., Hauge, S., Huglen, Ø., Kieran, O., Kirwan, B., Rettedal, W. K., Skåren, T. and Thomas, J. J. (2000); Systematic Analysis of Operational Safety of FPSOs Reveals Areas of Improvement. Presentation at the *SPE International Conference on Health, Safety and the Invironment in Oil and Gas Exploration and Production* held in Stavanger, Norway, June 26-28, 2000. SPE 61175, Society of Petroleum Engineers Inc.

Vinnem, J. E. (2001); *Operational safety of FPSOs: Initial summary report*. Health & Safety Executive, HSE OTO Report 2000/086. Norwegian University of Science and Technology (NTNU). HSE Books, Norwich.

Vinnem, J. E. (2003a); Modellering av HOF i forbindelse med risikoanalyse av FPSOer (Modelling HOF i connection with risk analysis of FPSOs). Presentation given at workshop within the research programme "HSE Offshore – decision support" at Rogalandsforskning on January 16th. No official report is so far published.

Vinnem, J. E. (2003b); Conversation on telephone March 21st.

Widdowson, A. and Carr. D. (2002); *Human factors integration: Implementation in the onshore and offshore industries*. Health & Safety Executive, HSE Research Report 001. BAE Systems Defence Consultancy. HSE Books, Norwich.

Wiegmann, D. and Shappel, S. A. (2001); Applying the Human Factors Analysis and Classification System (HFACS) to the analysis of commercial aviation accident data. Paper at the *11th International Symposium on Aviation Psychology*. Ohio State University, Columbus.

Wilpert, B. (1995); Psychology in high hazard systems – Contributions to safety and reliability. Invited Keynote Address given at the *IV European Congress of Psychology*, Athens.

www.ogp.org.uk; *Human Factors …a means of improving HSE performance*. OGP brochures and annual reports. Organization of Oil and Gas Producers, London.

www.tripod.nl; *Tripod. Protect Your Assets. The next generation management tool*. Information folder 2002/2003. Tripod International BV, Ka Den Helder.

Zachariassen, S. (2002); Oljeindustrien i Norge – hva er det? (The Norwegian oil industry – what is that?) Lecture within *"HMS-petroleum – prosjekt fysisk arbeidsmiljø". Fellesseminar* ("HSE-petroleum – project physical work environment". Common seminar) in Bergen on December 4th 2002.

Øien, K. and Sklet, S. (1999); *Bruk av risikoanalyser i driftsfasen, etablering av sikkerhetsindikatorer og modellering av organisatoriske faktorers effekt på risikonivået – en "state of the art" beskrivelse*. SINTEF-rapport STF38 A99416. SINTEF Teknologiledelse, Trondheim.

Øien, K. and Sklet, S. (2001); *Metodikk for utarbeidelse av organisatoriske risikoindikatorer*. SINTEF-rapport STF38 A00422 (on behalf of NPD). SINTEF Teknologiledelse, Trondheim.